THE DISCOVERERS by Daniel Boorstin

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Daniel J. Boorstin

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The ancient German communities, Tacitus reported nearly two thousand years ago, held their meetings at new or full moon, "the seasons most auspicious for beginning business."

Despite or because of its easy use as a measure of time, the moon proved to be a trap for naive mankind. For while the phases of the moon were convenient worldwide cycles which anybody could see, they were an attractive dead end. What hunters and farmers most needed was a calendar of the seasons--a way to predict the coming of rain or snow, of heat and cold. How long until planting time? When to expect the first frost? The heavy rains?

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The first puzzle is why it was the Egyptians. They had no astronomical instruments not already well known to the ancient world. They showed no special genius for mathematics. Their astronomy remained crude compared with that of the Greeks and others in the Mediterranean and was dominated by religious ritual. But it seems that by about 2500 B.C. they

had figured out how to predict when the rising or setting sun would gild the tip of any particular obelisk, which helped them add a glow to their ceremonies and anniversaries.

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But very early the Egyptians found that twelve months of thirty days each could provide a useful calendar of the seasons if another five days were added at the end, to make a year of 365 days. This was the "civil" year, or the "Nile year," that the Egyptians began to use as early as 4241 B.C.

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Why a seven-day week? The ancient Greeks, it seems, had no week. Romans lived by an 8-day week. Farmers who worked in the fields for 7 days came to town for the eighth day--the market day (or nundinae). This was a day of rest and festivity, a school holiday, the occasion for public announcements and for entertaining friends. When and why the Romans fixed on 8 days and why they eventually changed to a 7-day week is not clear. The number seven almost everywhere has had a special charm. The Japanese found seven gods of happiness, Rome was set on seven hills, the ancients counted seven wonders of the world, and medieval Christians enumerated seven deadly sins. The Roman change from eight to seven seems not to have been accomplished by any official act. By the early third century A.D. Romans were living with a 7-day week.

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The Greeks, too, were torn between wanting to know the good news and fearing to know the bad. Their medical astrologers divided the whole sky according to the signs of the zodiac, then assigned a particular stellar force to each part of the body. Then Greek anti-astrologers attacked the whole dogma of astral forces with auguments that would last into modern times. The names assigned to the stars, the anti-astrologers argued, were quite accidental. Why should this planet be called Mars and that Saturn or Venus? And why did the astrologers limit their horoscopes to human beings? Would not the same astral fortunes govern all animals? And how could astrologers explain the different fortunes of twins? The Epicureans, whose philosophy was built on the belief in each man's freedom to shape his destiny, attacked astrology as a way of making men think they were mere slaves of the stars.

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Yet the life of this encyclopedic genius remains a mystery. Probably descended from Greek immigrants, Ptolemy (90-168) lived in Egypt during the reigns of Emperors Hadrian and Marcus Aurelius. His Alexandria had continued to be a great center of learning even after its famous library was burned by Caesar in 48 B.C.

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Water, that wonderful, flowing medium, the luck of the planet--which would serve humankind in so many ways, and which gives our planet a special character--made possible man's first small successes in measuring the dark hours. Water, which could be captured in any small bowl, was more manageable than the sun's shadow. When mankind began to use water to serve him for a timepiece, he took another small step forward in making the planet into his household. Man could make the captive water flow fast or slow, day and night. He could measure out its flow in regular, constant units, which would be the same at the equator or on the tundra, winter or summer. But perfecting this device was long and difficult. By the time the water clock was elaborated into a more or less precision instrument, it had already begun to be supplanted by something far more convenient, more precise, and more interesting. Yet, for most of history, water provided the measure of time when the sun was not shining. And until the perfection of the pendulum clock about 1700, the most accurate timepiece was probably the water clock. During all those centuries, the water clock ruled man's daily--or, rather, his nightly--experience.

The outflow type was an alabaster vessel with a scale marked inside and a single hole near the bottom from which the water

dripped. By noting the drop in the water level inside from one mark to the next mark below the scale, the passage of time was measured. The later inflow type, which marked the passing time by the rise of water in the vessel, was more complicated, as it required a constant source of regulated supply. Even such simple devices were not without their problems. In cold climates the changing viscosity of the water would be troublesome. But, in any climate, to keep the clock at constant speed, the hole through which the water poured must not become clogged or worn larger. The outflow clocks posed another minor problem because the speed of flow depended on the water pressure, and that always varied with the amount of water left in the bowl. The Egyptians therefore slanted the walls of the vessel so that, as the amount of water decreased, the pressure remained constant by being concentrated on a smaller area.

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But the hourglass, measuring time by dripping sand, comes late in our story. Sand was, of course, less fluid than water, and hence less adapted to the subtle calibration required by the variant "hours" of day and nightin early times. You could not float an indicator on it. But sand would flow in climates where water could freeze. A practical and precise sandglass required the mastery of the glassmaker's art.

We hear of sand hourglasses in Europe in the eighth century, when legend credits a monk at Chartes with their invention.

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Not until the fourteenth century did Europeans devise mechanical timepieces. Until then, as we have seen, the measuring of time was left to the shadow clock, the water clock, the sandglass, and the miscellaneous candle clocks and scent clocks. While there was remarkable progress five thousand years ago in measuring the year, and useful week clusters of days were long in use, the subdivided day was another matter. Only in modern times did we begin to live by the hour, much less by the minute.

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It was around 1330 that the hour became our modern hour, one of twenty four equal parts of a day. This new "day" included the night. It was measured by the time between one noon and the next, or, more precisely, what modern astronomers call "mean solar time." For the first time in history, an "hour" took on a precise, year-round, everywhere meaning.

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The great opportunity for the Jesuits came when an eclipse was

expected on the morning of June 21, 1629. The Imperial Astronomers predicted that the eclipse would occur at 10:30 and would last for two hours. The Jesuits forecast that the elipse would not come until 11:30 and would last only two minutes. On the crucial day, as 10:30 came and went the sun shone in full brilliance. The Imperial Astronomers were wrong, but were the Jesuits right? Then, just at 11:30, the clipse began and lasted for a brief two minutes, as the Jesuits had predicted. Their place in the Emperor's confidence was now secure, and the door of China which Ricci had set ajar was opened to the science of the West. The Imperial Board of Rites begged the Emperor to command revision of the calendar, and on September 1 the Emperor ordered the Jesuits to begin the work. Incidentally, with their Chinese collaborators they translated Western books on mathematics, optics, hydraulics, and music, and they began building telescopes for China. At the very moment when, in Rome, Galileo was being tried by the Pope for his heresies, Jesuits in Peking were preaching the Galilean gospel.

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The first gear-cutting machine of which we have any record is the work of an Italian craftsman, Juanelo Torriano of Cremona (1501-1575), who went to Spain in 1540 to make an elegant large planetary clock for Emperor Charles V. Torriano spent twenty years planning a time-

piece with eighteen hundred gear wheels and then three and a half years building it. "So every day (not counting holidays)," his friend reported, "he had to make...more than three wheels that were different in size, number and shape of teeth, and in the way in which they are placed and engaged. But in spite of the fact that this speed is miraculous, even more astounding is a most ingenious lathe that he invented...to carve out with a file iron wheels to the required dimension and degree of uniformity of the teeth...no wheel was made twice because it always came out right the first time."

The screw, like the gear, was essential for a new world of machines. Its prototypes, like those of the gear, go back to the time of Archimedes or before. An ancient Greek scientist, Hero, may have devised a screw-cutting tool. But making a simple screw long remained a difficult operation. Until the mid-nineteenth century, when finally screws were made with points, it was always necessary in advance to prepare a hole for the full length of the screw.

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The clock stimulated new talents, new kinds of understanding and imagination. In the age of the French Revolution, Condorcet, the mathematician-philosopher and encyclopedist, while praising an inventor of improvements in silk-weaving machinery, observed:

Generally speaking, people have a very erroneous idea of the type of talent proper to the ideal mechanician. He is not a geometrician who, delving into the theory of movement and the categories of phenomena, formulates new mechanical principles or discovers unsuspected laws of nature.... In most other branches of science are to be found constant principles; a multitude of methods offer to the genius inexhaustible possibilities. If a scholar poses himself a new problem, he can attack it fortified by the pooled knowledge of all his predecessors. No elementary textbook contains the principles of this [new] science; no one can learn its history. The workshops, the machines themselves, show what has been achieved, but results depend on individual effort. To understand a machine it has to be divined. This is the reason why talent for mechanics is so rare, and can so easily go astray, and this is why it is hardly ever manifested without that boldness and the errors which, in the infancy of science, characterize genius.

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The Protestant Reformation, which divided Western Christendom, had brought a new era of upheaval, persecution--and mobility. In 1517 Luther nailed up his provacative 85 Theses on the door of All Saints Church in Wittenberg, and so opened the Reformation in Germany. Within two years Zwingli was preaching reformation in Zurich. Within another

decade Calvin announced the Reformation in France. Banished from Paris, Calvin took refuge in Basel, where he published his Institutes of the Christian Religion (1536), the first textbook of Protestant Christianity. Int he next decades the thousands who followed Calvin to Geneva made that city a center for European refugees.

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The older view of the movement of physical bodies, as expounded by Aristotle, was that nothing moved unless it was constantly being pushed by some outside force. But by the time the first mechanical clocks were striking in the town belfries of Europe, an interest in predictable regularities was growing--toward a new theory of motion. Now, it was argued, things kept moving because of forces originally imprinted on them (vis impresa) that simply continued to operate. De' Dondi's elegant model of a clockwork universe, recently completed, was already astounding the scholarly world. In the late fourteenth century an influential French popilarizer of science, Bishop Nicole d'Oresme (1330?-1382), created the unforgettable metaphor: a clockwork universe, God the perfect clockmaker! And "if anyone should make a mechanical clock," Oresme asked, "would he not make all the wheels move as harmoniously as possible?"

God the Clockmaker created each quite independently of the other, then wound up both of them and set them going so they are in perfect harmony. When I decide to life my arm, I may think that my mind is acting on my body. But really both move independently, each a part of God's perfectly harmonized clockwork.

This fertile mother of machines was the missing link between man's own efforts to master his physical universe and his awed reverance before his Creator. In the seventeenth century the pioneer Puritan physicist and founder of the Royal Society, Robert Boyle (1627-1691) saw the universe as "a great piece of clock work," and his Catholic contemporary Sir Kenelm Digby (1603-1665) agreed that the universe was just that. The Newtonian universe soon elevated God from a clockmaker to a master engineer and mathematician. Now the universal laws that governed the smallest portable watch also governed the movements of the earth, the sun, and all the planets.

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The contrast to China is dramatic and illuminating. There, circumstances comspired to prevent publicity. The first spectacular mechanical clockworks in China, as we have seen, were made not to mark the hour but to mark the calendar. And the science of the calendar--both of its making and of its meaning--was hedged in by government secrecy. Each Chinese dynasty was symbolized, served, and protected by itw own new calendar. Between the first unification of the empire in the third century B.C. (c. 221) and the end of the Ch'ing, or Manchu, dynasty in 1911, about one hundred different calendars were issued, with a name identifying it with a particular dynasty or emperor. These were not required by ad-

vances in astronomy or in the technology of observation, but were needed to put the cachet of the heavens on the authority of a new emperor. Private calendar-making was punished as a count of counterfeiting--as both a threat to the security of the Emperor and an act of lese majeste. The French Jesuit and translator of Ricci, Nicholas Trigault, reported in the early seventeenth century that the Ming emperors "forbad any to learn this Judiciall Astrology but those which by Hereditary right are thereto disigned, to prevent Innovations."

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From earliest times in China an astronomical observatory was an essential part of the cosmological temple, the ruler's ritual headquarters. As the central government became stronger and better organized, Chinese astronomy, by contrast with astronomy in ancient Greece or medieval Europe, became more and more official and governmental. This meant, of course, that Chinese astronomy became increasingly bureaucratic and esoteric. There the technology of the clock was the technology of astrological indicators. Just as in the West the machinery for minting coins, for printing paper money, or for manufacturing gunpowder was tightly controlled, so in China were calendrical timepieces.

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According to popular astronomy, the lowest of the seven planetary spheres was the moon, whose ether was nearest the earth's impure atmosphere. Pythagoreans and Stoics imagined souls returning to earth just after they had

crossed the circle of the moon. Therefore "sublunary" (beneath the moon) came to describe everything terrestrial, mundane, or ephemeral. Perhaps, as European folklore suggested, each person had his own star--bright or dull, according to his station and his destiny--which was illuminated at his birth and disappeared at his death. A shboting star,t hen, might signify some person's death. "Were there then only two starts at the time of Adam and Eve," wondered Bishop Eusebius of Alexandria in the fifth century, "and only eight after the Flood when Noah and seven other persons alone were saved in the Ark?" Everyone was born under either a lucky or an unlucky star. The Latin astrosus (ill-starred) meant unlucky, and today we still thank our "lucky stars."

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It is easier to recount what happened than to explain satisfactorily how it happened or why. After the death of Ptolemy, Christianity conquered the Roman Empire and most of Europe. Then we observe a Europe-wide phenomenon of scholarly amnesia, which afflicted the continent from A.D. 300 to at least 1300. During those centuries Christian faith and dogma suppressed the usual image of the world that had been so slowly, so painfully, and so scrupolously drawn by ancient geographers. We no longer find Ptolemy's careful outlines of shores, rivers, and mountains, handily overlaid by a grid constructed on the best-known astronomical data. Instead, simple diagrams authoritatively declare the true shape of the world, though they are only pious caricatures.

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From the earliest political records of the Ch'in era (221-207 B.C.), we find humerous references to maps and their uses. China, unified in 221 B.C., was both the creature and the creator of a vast bureaucracy, which had to know the features and the boundaries of its extensive regions. The Rites of Chou (1120-256 B.C.) had required the Director-General of the Masses to prepare maps of each feudal principality and register its populations. When the Chou emperor toured his realm, the Geographer-Royal was at his side explaining the topography and products of each part of the country. Under the Han dynasty (202 B.C.-A.D. 220) maps appear again and again as the indispensable apparatus of empire.

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The great age of Christian pilgrimage had begun in the tenth century. Muslims were generally tolerant, if contemptuous, of these passionate "unbelievers." But as the distant Holy Land became less accessible, pious Christians found the balm of pilgrimage nearer home. They produced a hybrid literature of history, sociology, myth, and folklore. In the popular Guide de Pelerin one could read of the pilgrim who asked a woman in Villeneuve for a piece of the loaf of bread she was baking under hot ashes in her oven. She refused, and when she went for her loaf, she found only a round stone. Other pilgrims en route in Poitiers searched a whole street before they could find anyone to lodge them. That very night all houses in the street burned--except the one that had given them hospitality. Popular epics like the Chansons de Geste

The Crusades would be one of the most miscellaneous, most unruly movements in history. A portent of things to come was Peter the Hermit. He was appropriately miscalled the Hermit because he usually wore a hermit's cape, but he was by no means a hermit, for he loved crowds and knew how to move them. Peter set up his own corps of recruiting agents and began gathering his motley pilgrim army in the county of Berry in central France. By the time he reached Cologne in western Germany on Holy Saturday, April 12, 1096, some fifteen thousand pilgrims of all ages, sexes, shapes, and sizes had joined his party. "All the West and all the barbarian tribes from beyond the Adriatic as far as the Pillars of Hercules," a Byzantine princess, Anna Comnena, fearfully reported, "were moving in a body through Europe towards Asia, bringing whole families with them." The arrival of Peter's horde at Constantinople brought new troubles. There they joined forces with Walter the Penniless, and moved on toward the Holy City, plundering as they went. One group under Rainald, an Italian nobleman, sacked Christian villages en route, tortured their inhabitants, and were even reported to roast Christian babies on spits over open fires. The Byzantine emperor Alexius I tried to persuade adventuring knights to submit to his rule, but the more ambitious of them conquered and pillaged to establish new kingdoms of their own. These Christian forces defeated the Turks in several battles and entered Jerusalem in triumph in July 1099, so bringing to an end what came to be called the First Crusade.

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The Mongol empires were land empires, twice the size of the Roman Empire at its greatest extent. Genghis Khan and his hordes came down from Mongolia to Peking in 1214. In the half-century after, they took nearly all eastern Asia, then turned westward across Russia, even into Poland and Hungary. When Kublai Khan came to the Mongol throne in 1259, his empire reached from the Yellow River in China to the shores of the Danube in eastern Europe and from Siberia to the Persian Gulf. The Mongol Khans, from Genghis Khan through his sons and grandsons--Batu Khan, Mangu Khan, Lublai Khan, and Hulaga--were as able a dynasty as ever ruled a great empire. They showed a combination of military genius, personal courage, administrative versatility, and cultural tolerance unequaled by any European line of hereditary rulers. They deserve a higher place and a different place than they have been given by the Western historian.

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Despite the alarms of Christian rulers, and the Tartar massacres of Poles and Hungarians, the Tartars would prove powerful allies against the Muslims and the Turks who blocked the eastward path. For the Tartars, after succeeding in their campaigns against the "Assassins," or Ismailians, on the southern shores of the Caspian, went on to overcome the Caliph of Baghdad and Syria. The conquering Tartar general in Persia had actually sent his embassy to Saint Louis, King Louis IX of France, who was then at Cyprus on a Crusade, offering an alliance and asking for collaboration. If Christian kings and the Pope himself had been willing to join in such an alliance, they might have shared the glory and the profit of the conquest of the Muslim Turks, and eventually have accomplished the aims of

the Christian Crusades with pagan help. But instead of postponing conversion until after a worldly victory, they determined to ally only with fellow Christians, and so spent themselves on futile efforts to convert the Khans before joining them as allies. This mistake of judgment decisively shaped the future of much of Asia. The power of Islam was then in retreat. If Christian leaders had only been willing first to become comrades in arms against a common enemy, Pope Innocent IV and the Christian powers might soon enough have made them comrades in faith.

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Bu somehow the Mongols had forgotten to suppress the Chinese custom, at the coming of the full moon, of exchanging little round full-moon cakes, decorated with pictures of the moon hare and which, like a fortune cookie, carried a piece of paper inside. The wily rebels, we are told, used these innocent-looking moon cakes for their messengers. Inside were instructions for the Chinese to rise and massacre the Mongols at the time of the full moon in August 1368.

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It is not surprising, then, that manuscript coast pilots were few. From the whole period of the Great Interruption, the fourth until the fourteenth century, no mariner's charts survived. In that age of widespread illiteracy,

sailors passed on their traditional knowledge by word of mouth.

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As we have seen, it was not until the eighteenth century that a seafaring clock made it possible for mariners to define their longitude with a precision sufficient to enable them to use longitude to guide their return to where they had been, and to guide those who wanted to follow them. Besides all these problems, leaving the Mediterranean obviously carried the risk of being driven off course into the trackless open ocean.

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The Catalan Atlas aimed to provide a "mappamundi, that is to say, image of the world and of the regions which are on the earth and of the various kinds of people who inhabit it." It expressed the dominant interests of European mariners of the Age of the Land that was nearing its end. The east-west stretch that was the center of their world was depicted on twelve leaves mounted on boards to fold like a screen. It did not show northern Europe, northern Asia, or southern Africa, but did show the Orient and the little that was known of the Western Ocean. By contrast with Christian maps, it was a triumph of empiricism. It showed what could be learned by adding up the experiences of countless individuals, including Arabic seamen and the very latest European world travelers. Of course, the map-makers had to start with something and they inevitably started with the familiar T-O circular forms. Jeru-

salem is still near the center, and there too are the tribes of Gog and Magog held back by the "Caspian" mountains, and other relics of the orthodox landscape. But this is essentially a portolana atlas, which means that the seacoasts of the Black Sea, of the Mediterranean, and of Western Europe are delineated from the "normal" portolano, from the countless sketches of these coasts made by active seamen and recorded on their coastal guides. Abraham Cresques also drew on the reports brought back by recent travelers to Asia.

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Ptolemy's great contribution was the scientific, quantitative spirit. His scheme of latitude and longitude, unlike the decorative wind rose, was uniform and universal. Any two maps properly made according to his prescription would be precisely alike

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Manuscripts of Ptolemy's geography, in the Greek language, come to us from the early thirteenth century. But since the ability to read Greek, even among the learned in Europe, was rare, knowledge of Ptolemy's work could not spread until it was translated into Latin. In 1400 a copy of Ptolemy in Greek was brought from Constantinople to Florence by Palla Strozzi (1373-1462), one of the family who used the wealth acquired in commerce to become patrons of learning. There the geography was translated from Greek into Latin by the celebrated Manuel Chrysoloras (1355-1415) and his pupils. By

fifteenth century numerour Latin manuscripts of Ptolemy's geography were circulating in Western Europe. More than forty from this period have survived. SOme of these manuscripts were accompanied by what purported to be Ptolemy's maps, usually twenty-seven in number. The earliest printed version of this Latin translation (Vicenza, 1475) produced only the texts. Modern scholars are puzzled over what became of Ptolemy's work during the Great Interruption. Where were his text and his maps during the millennium between Ptolemy's death and the revival of his work? It now seems likely that only the first theoretical book of the Geography survives substantially as Ptolemy wrote it. The remaining books, including the lists of cities located by his system and the maps, appear to have been compiled over the centuries by Byzantine and Arabic scholars and fathered on his eminent name.

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One of these latter-day Venetian merchants was Nicolo de' Conti, who traveled for twenty-five years after leaving Venice in 1419.

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Unlike Columbus, who would aim straight for the Indies, Price Henry the Navigator had a larger, a vaguer, and more modern destination--true to his horoscope. "The noble spirit of this prince," the admiring reporter Gomes Eanes de Zurara explained "was ever urging him both to begin and to carry out very great deeds....he had also a wish to know the land that lay beyond the isles of Canary and that Cape called Bojador, for that up to his time, neither by writings, nor by the memory of man, was known with any certainty the nature of the land beyond that Cape....it seemed to him that if he or some lord did not endeavour to gain that knowledge, no mariners or merchants would ever dare to attempt it, for it is clear that none of them ever trouble themselves to sail to a place where there is not a sure and certain